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THE RELATIONSHIP BETWEEN MILK COMPOSITION AND SWISS CHEESE YIELD

by

Gheyath H. Majeed

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Nutrition and Food Sciences

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Gheyath H. Majeed

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ABSTRACT

The Relationship Between Milk Composition
and Swiss Cheese Yields

by

Gheyath H. Majeed, Master of Science

Utah State University, 1982

Major Professor: C. Anthon Ernstrom
Department: Nutrition and Food Sciences

Eighty-five samples of milk and Swiss cheese made from the same milk were collected at Cache Valley Dairy Association, Smithfield, Utah, between August, 1979, and July, 1980. The weights of the milk, Swiss cheese and the trim were carefully recorded. The milk samples were analyzed for fat and protein, and the cheese samples were analyzed for fat, protein and moisture. An attempt was made to predict Swiss cheese yields from the fat and protein content of the milk and the moisture content of the cheese.

The data were analyzed statistically by Gauss-Newton non-linear least squares method of iteration. Three formulas for predicting Swiss cheese yield were derived. The differences among the three formulas in predicting actual yield were insignificant. A good comparison was demonstrated between Swiss cheese yield and fat and protein in milk.

The effect of season on cheese yield was also evaluated. The highest yield of Swiss cheese was in December and the lowest yield was in July. This corresponded with high and low levels of fat and protein in the milk. (63 pages)

INTRODUCTION

Predicting cheese yield is important to the dairy industry because it makes possible the establishment of accurate values for milks of different compositions when used for cheese making. It also makes possible the computation of the relative profitability of manufacturing different cheese varieties. Moreover, it helps to standardize the cheese milk to a proper casein to fat ratio and helps for checking on losses during cheese making.

Cheddar cheese yield can be reasonably well predicted by Van Slyke and Price formula (52), which is:

$$Y = (0.93\ F + C - 0.1)\ 1.09/1-W$$

where

Y = Kilograms of Cheddar cheese per 100 kilograms of milk

F = Percent fat in milk

C = Percent casein in milk

W = Kilograms of water per kilogram of cheese

0.1 suggests that 0.1 kilograms of milk casein per 100 kilograms of milk is lost in the whey.

1.09 indicates that milk solids other than fat and casein plus added salt represents 9% of cheese fat and casein.

There are a number of other yield formulas that also have been proposed by other workers (13), but the Van Slyke and Price formula has received the best acceptance and is even used as a basis for milk pricing (15). This formula cannot predict Swiss cheese yield or the yield of other cheese varieties (22).

The purpose of this study was to derive an equation to predict Swiss cheese yield from milk fat and protein and determine the effect of seasons on yield. Such a formula would not only make it possible to establish the value of milk for Swiss cheese making, but also enable cheese factories to compute the relative profitability of making Swiss cheese and Cheddar cheese from milk with different compositions.

REVIEW OF LITERATURE

Importance of the Cheese Industry

Total world production of milk in 1980 was 405.7 million metric tons, which was greater by one percent than 1979 production (50). Cow milk production was 385.5 million metric tons in 1980. Production increase has been due to improved genetics and feeding practices which caused increased milk yield per cow, and to a continuous increase in cow numbers.

In most countries of the world milk production increased from 1979 to 1980, although in a few other countries milk production decreased. In the United States, 1980 milk production was 58.3 million metric tons which was greater by 4.1% than 1979 production (49) and is expected to be greater by two to three percent in 1981 over 1980. In Canada, France and Japan, milk production in 1980 was greater by 5%, 4.8% and 1% respectively than in 1979, and increases of 2%, 3-4% and 0% respectively are expected in 1981 (50). On the other hand, milk production in Australia and the Soviet Union decreased in 1980 compared to 1979. The world condition indicates that world milk production in 1981 is expected to be greater by 1% than 1980 production (50).

The increase of world milk production resulted in an increase in cheese production in 1980 over 1979. World cheese output in 1980 was around a million metric tons which was greater by 3% than 1979 production, and is expected to increase by 2-3% in 1981 (50).

In the United States, 2,123,000 metric tons of cheese were manufactured in 1980 and this figure is expected to increase by 5% in 1981 (50). Europe produced about 5,172,000 metric tons of cheese in 1980 which was greater by 3% than in 1979, and is expected to increase by 2% to 3% in 1981 over 1980. France produced one-third of Europe's output of cheese (50). The 1980 production in France was greater by 4.3% than 1979 production. Other countries such as Argentina, Brazil and Canada also increased their 1980 cheese production by 3% over 1979.

Cheese consumption is increasing continuously in most countries of the world. In the United States, Canada, Europe and Australia, cheese consumption in 1980 was 1,793,000, 187,000, 4,738,000 and 92,000 metric tons, respectively, and is expected to increase by 2%, 4.3%, 1.6% and 4.3% in 1981 (50) (Table 1).

Swiss Cheese

Swiss cheese is a very important dairy product in the United States and some other countries. In 1979, 14,353,636,000 kilograms of milk were used for cheese manufacturing (excluding cottage cheese) in the United States (47). This amount of milk produced 1,688,768,200 kilograms of cheese. Swiss cheese produced was 96,946,818 kilograms which represented about 5.7% of the total cheese production. In 1978, the amount of milk used for cheese manufacturing was 13,599.55 million kilograms. About 1,599,856,400 kilograms of cheese (excluding cottage cheese) was produced, which included 95,164,545 kilograms of Swiss cheese. This represented about 6% of the total cheese produced in

Table 1. Cheese consumption in some countries or regions, 1977-1980.

Country or Region	1977	1978	1979	1980
		$\times 10^3$ metric tons		
Australia	70	82	86	92
Canada	154	154	175	187
Europe	3625	3764	3861	3973
United States	1597	1700	1751	1793

1978. In 1977, the amount of milk used for cheese manufacturing was 13,120.455 million kilograms. About 1,526.6 million kilograms cheese (excluding cottage cheese) were produced which included 86,026,800 kilograms of Swiss cheese. This represented 5.6% of the total cheese manufactured in 1977. In 1976, the amount of Swiss cheese produced represented also about 5.9% of the total cheese manufactured (Table 2).

Swiss cheese production was higher in 1979 than in 1978, 1977, 1976, 1975 or 1972 by 1.8%, 11.3%, 8%, 18.5%, and 16.6%, respectively, while whole milk American cheese was higher by 5.2%, 6.6%, 6.3%, 24%, and 24.8%, respectively. The increase in all Italian varieties from 1978 to 1979 was 18.6% (Table 3) (47).

United States imports of Swiss cheese in 1979 were 42,714,000 kilograms, an excess of 4,707,270, 8,665,450 and 24,394,500 kilograms over 1978, 1977; and 1970 imports respectively (51). The 1979 imports of Swiss cheese represented 37.8% of all imported cheese. American cheese imports represented only 7.2% of total imported cheese.

Italian cheese represented 3.1% of imported cheese. In 1973, American, Italian and Swiss cheese represented 6.7%, 6.6% and 20% of total cheese imports (Table 4). In 1980, Swiss cheese imports during June to August were down 30% compared with 1979. Through August they were 78% of 1979 imports. American type cheese imports were 16% lower in 1980 than in 1979 (48).

Table 2. Amount of milk used and cheese produced from 1975-1979 in the United States.

Year	Total cheese produced X 10^3 kg. (excluding cottage)	Swiss cheese X 10^3 kg.	Milk used for all types of cheese (excluding cottage) X 10^6 kg.
1975	1,275,232.7	78,815.3	10,833.1
1976	1,506,046.4	89,052.4	13,046.6
1977	1,523,405.8	85,846.4	10,824.9
1978	1,596,501.8	94,965	13,571
1979	1,685,190.4	96,743.5	14,323.5

Between 1969 and 1979, per capita consumption of Swiss cheese increased 60% (48). Per capita consumption of Swiss cheese in 1978 was 1.37 pounds, while in 1977 it was 1.24 pounds. There was an increase of 7.3% in per capita Swiss cheese consumption in 1978 over 1977 and an increase of 18.25% over 1975 (46) (Table 5).

Due to the importance of Swiss cheese in the United States, it is clear that controlling its yields and determining the factors which affect the yields are important to the dairy industry.

Table 3. Some cheese varieties produced in the United States in 1971 and 1975-79.

Type of Cheese	1971	1975	1976	1977	1978	1979
			X 10^3 kg.			
Swiss cheese	69,782	78,815.3	89,052.4	85.846.4	94,965	96,743.5
American cheese	685,608.4	750,504.8	929,332.7	926,717.7	940,842.2	992,325.3
Italian cheese	205,867.8	304,750.5	339,017.2	359,920.5	397,033.9	24,641.4

Table 4. United States imports of Swiss and Cheddar cheese in 1974-1979.

Year	Swiss Cheese X 10^3 kg.	Cheddar Cheese X 10^3 kg.	Italian Cheese X 10^3 kg.	Total Cheese Imports X 10^3 kg.
1974	35,882.7	48,533.9	4,613	143,605.5
1975	26,717.4	4,808	5,173.2	81,385.8
1976	34,638.6	3,621.5	5,673.9	94,019.3
1977	33,977.2	4,235.2	5,055.7	94.982.2
1978	42,009.4	4,875.2	4,676.9	109,853.3
1979	42,624.5	4,652.5	3,489	112,621.5

Table 5. Per capita consumption of selected cheese varieties in the United States (1975-1978).

Year	Swiss	Brick	Blue	Mozzarella	Parmesan	Cheddar
1975	0.5080	0.0408	0.0726 kg.	0.9797	0.0816	2.7669
1976	0.5806	0.0408	0.3583	1.075	0.1270	2.9937
1977	0.5624	0.0317	0.3719	1.1476	0.1225	3.1298
1978	0.6214	0.0363	0.4173	1.2564	0.1315	3.2205

Factors Affecting Cheese Yields

There are three main factors which determine the yield of all kinds of cheese (52). They are:

1. The percentages of fat and casein in the milk.

2. The percentages of fat and casein lost during cheese making.

3. The amount of water retained in the cheese.

A linear relationship was observed by Van Slyke and Price (52) between the amount of fat and casein in the milk and the yield of Cheddar cheese. Many other workers also have shown the relationship between cheese yield and milk composition, especially the casein and fat content of the milk (11, 20, 21, 23, 27, 43).

Joost et al. (20, 21) found a correlation between milk composition and the yield of Cheddar and blue cheese. Kyurkchyan (23), showed an increase of 3% in cheese yield by increasing milk proteins by 0.1%. Steinsholt and Ystgaard (43) found that cheese yield was positively correlated with the fat and casein content of milk.

Chapman (11) indicated that Cheddar cheese yield depends upon the fat and casein in milk and moisture in the curd. She predicted that milk with a fat:solids-not-fat ratio of 0.46 to 0.48 would be most economical for cheese production and mentioned that standardization of milk is important to obtain the greatest amount of cheese for each pound of fat in the milk. This, of course, is based on the assumption that the value of cheese milk is determined completely by the fat value. In such a case, one would be interested in getting maximum yield per pound of fat purchased and in reducing the fat content of the cheese to the legal minimum. The advisability of following this practice will depend on the relative value of fat in the cheese as opposed to its value in other products.

Factors Affecting Casein and Fat Content of Milk

Casein and fat content of milk are affected by many factors. Several reports indicate that composition of milk differs due to season (13, 33, 34, 38, 41, 43, 54), breed of cow (2, 10, 13, 25, 45), age of cow (4, 19, 45, 53, 54, 56), stage of lactation (25, 28, 34, 54, 56), feeding (11, 27, 28, 39, 41, 42, 52, 54), milk handling (12, 17, 30, 33), udder health (19, 37, 55), manufacturing steps (13, 33, 35, 52) and heat treatment of cheese milk (13, 14, 31, 32).

Seasonal Effects

Many reports indicate that composition of milk is affected by season (13, 16, 29, 33, 34, 38, 41, 42, 54), but Legates (26) claimed that it is difficult to separate the influence of season from nutritional factors.

Grappin et al. (16) found that fat and protein were lower in summer than in autumn and winter with a slight rise in protein in May. Mariani et al. (29) found that fat was highest in October and lowest in March. Protein was highest in November and lowest in March.

There are fluctuations in casein due to season (18, 43, 44, 54). Waite et al. (54) indicated that there was a rise in milk casein concentration during May and June and again in September. Szijarto et al. (44) found that casein increased slightly during May, June and July and decreased during August, September and October, while Irvin (18) showed that protein was highest during June and lowest during April, May and July. Steinsholt and Ystgaard (43) found that the casein content was at a minimum in April, May and June and at a maximum during September, October and November.

Milk fat has been considered to be the major factor controlling cheese yield because it is the most variable factor during the year (13). Milk produced in autumn and winter is higher in fat than that produced in spring and summer (16, 34). Fat content of milk decreased during spring and reached a minimum in June and maximum in October (54). Olson (33) mentioned that milk fat concentration reached a minimum in August and a maximum in October. Steinsholt and Ystgaard (43) indicated that milk fat was at a maximum in October and at minimum in July. Schinckel (41) in Australia, indicated that fat content was highest during autumn and lowest during spring and summer (southern hemisphere).

Davis (13) indicated that the amount of milk required to make a specific amount of cheese is at a minimum in winter and a maximum in spring. This is due to the seasonal variations of fat and solids-not-fat in cheese milk. He mentioned also that maximum yield usually occurs during March and April; on the other hand, maximum and minimum values may occur at another period of the year. Steinsholt and Ystgaard (43) showed that minimum yield occurred from May to August because the milk had the lowest content of fat, total solids and casein, except in June. The highest yields were in October and November, when the milk had the highest fat, casein and total solids content.

Seasonal variations in goat's milk composition also have been observed by Ricordeau and Mocquot (38) in France. They claimed that variations in milk protein content accounted for 75% of the variation in cheese yield.

Breed of Cow

Casein and fat content of milk are affected by breed of cow as indicated by several authors (2, 10, 13, 25, 45). Davis (13) mentioned that the biggest factor influencing the composition of milk in any country is the breed of cow.

Cerbulis and Farrell (10) found that casein was the highest in Jersey milk and the lowest in Holstein milk. Brown Swiss milk had more casein than Guernsey and Ayrshire milk. They indicated that fat content was the highest in Jersey milk and lowest in Milking Shorthorn milk. Guernsey milk had higher fat than Brown Swiss, Ayrshire or Holstein milk. The highest fat content found by Turner (45), Armstrong (2) and Cerbulis and Farrell (10) was in Jersey milk (Table 6).

Ayrshire and Guernsey milk protein had the highest casein (79.3% and 78.7% respectively), while Holstein and Jersey milk had the lowest casein percentages (76.3% and 78.7%) (25).

Milk from Jersey cows would be better than milk from other breeds for cheese manufacturing because it has the highest casein as a percentage of milk protein (10). On the other hand, Chapman (11) claimed that the small even sized fat globules of Ayrshire cows' milk makes it very suitable for cheese manufacturing. Blake et al. (7) claimed that the variation in casein content of herd milk is not large.

Table 6. Fat, protein and solids-not-fat content of different breed's milk as listed by several authors.

Breed	Turner (45) fat %	Turner (45) protein %	Turner (45) SNF %	Larson (25) fat %	Larson (25) protein %	Armstrong (2) fat %	Armstrong (2) SNF %	Cerbulis & Farrell (10) fat %	Cerbulis & Farrell (10) protein %	Cerbulis & Farrell (10) casein %
Holstein	3.40	3.32	8.86	3.50	3.10	4.22	8.61	3.73	3.22	2.53
Jersey	5.37	3.92	9.54			5.51	9.46	5.42	4.22	3.39
Guernsey	4.95	3.91	9.66	5.00	3.90	4.99	9.32	4.76	3.70	2.88
Ayrshire	4.00	3.53	8.90			4.15	8.96	4.12	3.47	2.73
Brown Swiss	4.01	3.61	9.40			4.02	9.39	4.28	4.05	3.14
Milking Shorthorn								3.58	3.42	2.56

Age of Cow

The age of the cow also affects milk composition (5, 19, 45, 54, 56). Many studies have indicated that the solids-not-fat content of milk declines with age (4, 54, 56). Lactose and casein were mentioned as the solids-not-fat components which are affected by the age of cow (19). It was shown by Turner (45) that the average fat content decreased slightly with the age of the cow. Voigtlander (53) also found that fat, protein and lactose content of milk declined with age. This possibly results from increased milk production with age since the fat and protein in milk generally varies inversely with total milk production.

Stage of Lactation

Stage of lactation affects fat and protein content of milk (25, 28, 34, 54, 56). Waite et al. (54) indicated that the fat content decreased when milk yield increased, with most of the decrease taking place up to the 75th day of lactation. The fat rose slowly after that and increased markedly after the 195th day of lactation. Total protein and casein content decreased to a minimum at the 45th day of lactation then increased to a maximum at the 285th day of lactation. They indicated also that the average variation in the mean value for each component of the milk during the course of lactation is greater than that caused by seasonal changes.

Ling (28) mentioned that the second and third lactation gave milk with the highest level of fat and protein. The protein level declined steadily after the third lactation, while fat stayed relatively constant.

Parkhie et al. (34) indicated that milk yield steadily increased as it advanced from the first to the fourth lactation and that the content of all milk constituents except water, steadily decreased. The declines in fat and solids-not-fat were significant. Solids-not-fat was also found by Wilcox et al. (56) to be influenced by stage of lactation.

Feeding

Since 1930 feeding has been considered to affect solids-not-fat content of the milk (54). The solids-not-fat content of milk rose by 0.3-0.4% when cows were transferred from winter feeding to spring grazing (39). Any increase in solids-not-fat content with grazing is essentially an increase in protein content. Much of this change is due to casein.

Chapman (11) indicated that there was a rise in solids-not-fat content of milk with spring grazing resulting from the high nutritional value of spring grass compared to winter feed. Fat content was found to decrease. Schinckel (41) showed that during winter the quantity of feed was low but the quality (as judged by protein content) was high. During spring the feed was of high quality due to active pasture growth. There was a decline in the quantity and quality of feed during the summer period. In autumn, the feed was of low quality and quantity. Pasture protein content reached a maximum of about 24% in July and a minimum of about 8% in March. He noticed that a decline in butter fat production started in November which was due to the shortage of protein in the grass. He claimed that average dairy cows require about 16% of digestable crude protein in the feed, and it started to fall below this level in November. He mentioned also that cheese yield declined during the late summer which is probably due to the low feeding value of the pasture.

Ling (28) mentioned that reduction in fat content of milk occurred when cows were fed on flaked maize in conjunction with a low roughage supply. He mentioned also that the intake of low roughage levels with highly digestable carbohydrates caused the low fat content of milk. Protein did not seem to be influenced by feeding while fat percentage was. Fat was higher in winter than in summer.

Schingoethe et al. (42) found that feeding cows on whey prevented the large decrease in milk fat which occurs due to feeding high-grain rations (ground shell corn and soy bean meal with 1% urea and 5% molasses). They claimed that the minerals in the whey are the main components responsible for preventing the decrease in milk fat. Banks et al. (5) found that the use of a low-fat basal diet supplemented with different fat sources resulted in milk with a different fat to protein ratio.

Milk Handling

Milk handling may affect fat and casein content of milk (33). Cheese yield is reduced due to inadequate handling which causes churning of fat that disrupts fat globules and causes its loss in the whey. Casein may be lost due to proteolytic bacterial growth which causes a reduction in cheese yield (12, 17). Hicks (17) showed that 10% of milk protein was lost when high quality milk was stored at 5°C for 10 days. This loss was due to the growth of psychrotrophic bacteria which are proteolytic and lypotytic in nature. Cheese yield decreased as psychrotrophs increased because of degradation of fat and protein. This caused more loss of casein and fat in the whey.

McCaskey and Babel (30) found a loss of 28%-29% of milk protein when cheese was made from fresh raw milk. However, samples which were held for 7 days at 1°C lost 31.1% of their protein. Milk held at 5°C and 10°C for 7 days lost 39.9% and 36.9% respectively. The loss increased with lengthened storage time. This loss of protein was attributed to proteolytic action of psychrotrophic bacteria.

Udder Health

It was shown by Weaver and Kroger (55) that udder health affects the casein content of milk. They found that serum protein increased with the presence of somatic cells. This increase in serum protein caused an increase of total protein, but that casein and the somatic cell count were negatively correlated.

Rhodes (37) mentioned that milk with low somatic cell counts resulted in increased cheese yields, while mastitic milk reduced cheese yields.

At 640,000 cell/ml., the reduction in cheese yield was 0.31 pounds per 100 pounds of milk. He indicated also that somatic cells cause an increase in the permeability of the vascular and secretory system which causes the increase of serum proteins and the decrease of casein in milk.

Manufacturing Steps

Loss of fat and casein may occur at any stage during cheese manufacturing (33). For instance, loss of fat may occur during pumping with inadequately-sized pumps or improper separation of cream, which causes disruptions of fat globules (33). Loss of casein may occur due to violent agitation of the curd in the whey (13), or cutting curd when it is soft (52). Casein to fat ratio of cheese milk affects cheese yield as shown by many authors (22, 35, 52). More fat is lost in the whey as percent fat in milk increases. Kosikowiski (22) stated that the best casein to fat ratio to achieve the best yield in Cheddar cheese making is 0.7. However, this will result in about 51-52% fat in the dry matter of the cheese. Under current market conditions, it is more profitable to sell fat in cheese than in butter. Therefore, one can argue that a casein to fat ratio less than 0.7 provides a more profitable yield. It must be remembered that if the casein to fat ratio is too low, a lower percentage of fat is recovered in the cheese, and the moisture content must be reduced.

Heat Treatment

Heat treatment of milk affects cheese yield (1, 13, 14, 30, 31). El-Sadek and Motteleb (14) found that there was an increase of 3.33% in yield of cheese made from pasteurized buffalo milk compared to that made from raw buffalo milk. They claimed that this increase in yield was due to the production of a soft curd which was capable of holding more moisture than curd made from unheated milk. However, it is more likely that the increased yield resulted from incorporation of heat denatured whey proteins. Retention of other constituents (serum proteins) in pasteurized milk curd also increases cheese yield (13, 14).

Angevine (1) stated that cottage cheese yield is affected by pasteurization temperature higher than 72.8C or holding times longer than 17 seconds at this temperature or a combination of the two. Yields of cottage cheese were increased by 15.6% when heat treatment temperature of skim milk was increased from 61.8° to 79.4°C for 30 minutes because of the retention of whey proteins in the curd (31). Noznick and Bundus (32) claimed that heat treatment of cheese milk at 185°F for 15 minutes to 305°F for 0.7 seconds increased cottage cheese and Cheddar cheese yield by 10-20% due to the retention of whey proteins in the curd.

Relationship Between Fat and Casein

There is a relationship between milk fat and casein as mentioned by Van Slyke and Price (52). The relationship is affected by season, individuality of the cow, breed of cow, stage of lactation and feeding. The relation of fat and casein varies greatly in milk from different individuals. The percentage of fat and casein increases gradually during the period of lactation. The casein to fat ratio remained constant for the first seven months of lactation and then increased slightly. During May to October there was an average increase of 0.4% in casein when milk fat increased by 1% (52). Milk from Guernsey and Jersey breeds have higher fat and casein than Holstein and Ayshire.

Predicting Cheese Yields

Cheddar cheese yield has been predicted by Van Slyke and Price (52) as:

$$\text{cheese yield} = \frac{(0.93F + [C-0.1])\ 1.09}{1-W}$$

where:

0.93 suggests that 93% of milk fat goes to the cheese.

0.1 suggests that 0.1 kilograms of casein per 100 kilograms of milk is lost in the whey.

1.09 indicates that milk solids other than fat and casein plus added salt represent 9% of the cheese fat and casein.

F = percent fat in the milk.

C = percent casein in the milk.

W = kilograms of water per kilogram of cheese.

Besides the above formula, Davis (13) listed other formulas derived by other workers:

1. Babcock et al. 1910:

   Cheese yield = 1.1 fat + 2.5 casein

2. McDowell (1936) (using Van Slyke data):

   Cheese yield = 1.4 (casein + fat) + 1.04

   McDowell (1936) (Using his data):

   Cheese yield = 1.22 (casein + fat) + 2.32

3. Shelton (1937):

   $$\text{Cheese yield} = \left(F - \frac{4F}{100}\right) + \left(C - \frac{4C}{100} + \frac{22C}{100}\right) \times 2.26$$

which was explained as follows:

a. Loss of 4% of the fat in the whey.

b. Loss of 4% of the casein in the whey.

c. Non-casein solids-not-fat retained in cheese equivalent to 22% of the casein.

d. Cheese moisture content equivalent to 126% of solids-not-fat retained in cheese.

4. McDowell (1939):

yield = 0.96 fat + 2.67 casein

5. Van Dam and Janes (1931):

yield = fat + 1/3 solids-not-fat

6. Dergman and Joost (1953):

a. $\text{yield} = 0.91F + 0.77P + 0.48 + W(0.77P + 0.48)$

b. $\text{yield} = \dfrac{91F + 77P + 40}{100-S-W}$

where:

F = percentage fat in milk

P = percentage protein in milk

W = percentage water in cheese

S = percentage salt in water

7. Schulz and Kay (1957):

$\text{yield} = \text{net fat} + (0.75 + 0.825\ W_{ff})P$

where:

net fat = milk fat - whey fat

W_{ff} = moisture content of fat free cheese

The equation was simplified as:

yield = net fat + F(P)

where:

F = protein factor which varies with the moisture content of the fat free cheese.

F value for Cheedar cheese is 1.8 when moisture percentage in fat free cheese is 50% and for Swiss cheese is 1.56. Other values of F for other varieties of cheese were also given.

Joost et al. (19) derived the following formula for Cheddar cheese:

$$Y = 0.866f + 0.752p + 0.460 + \frac{W(0.75p + 0.460)}{100 - W}$$

where:

Y = cheese yield

f = percent fat in milk

p = percent protein in milk

W = percent moisture in the fat free fraction of the cheese

A formula for predicting blue cheese yield has been derived by Joost et al. (21):

$$\text{yield} = 0.95f + 0.725p + 0.660 + \frac{W(0.752p + 0.660)}{100 - W}$$

where:

f = percent fat in milk

p = percent protein in milk

W = percent moisture of fat free substance

All of the above formulas have been used to predict yields of different cheese varieties (most of them for Cheddar cheese), but the Van Slyke and Price formula has received the best acceptance and is even used as a basis of milk pricing (15). Other formulas for milk pricing have been proposed by other workers (8, 24), but the Ernstrom pricing program is being used most successfully (9).

METHODS AND PROCEDURES

Swiss Cheese Making

Swiss cheese was manufactured by Cache Valley Dairy Association, Smithfield, Utah according to the schedule in Table 7.

Sample Collection

Collection of milk and cheese samples from the Cache Valley Dairy Association, Smithfield, Utah, was started in August, 1979 and ended in July, 1980. One sample of milk was collected five minutes after the addition of the starter and before the addition of the rennet from each of two different Swiss cheese vats each week. Samples of the Swiss cheese were collected after they were removed from the brine tank by taking three plugs, one plug from each end of the Swiss cheese block and one plug from the middle of the block. Cheese and milk samples were kept refrigerated until analysis.

Milk Analysis

Milk samples were analyzed for fat and protein on a Milk-O-Scan 300 (A/S N. Foss Electric, Denmark; sold by Foss American Inc., Fishkill, N.J.).

Milk and Cheese Weights

Milk was measured in gallons by a calibrated dip stick after the addition of the starter, then converted to pounds by multiplying by a factor of 8.6. Cheese weight in pounds was taken prior to and after

Table 7. Swiss cheese making procedure at Cache Valley Dairy Association.

Operation	Time	Temp. °F	T.A. %	pH	Comments
Standardization					2.8% fat
Clarification					
Pasteurization	15 sec.	157			
Added starter	8:00 am	91			
Added rennet	8:55 am	91			
Cutting curd	9:25 am	91	0.104		curd is relatively weak
Predrawing of whey	9:30 am				stop agitation (8 inches from the original milk level)
Forworking	9:40 am				stir
Steam on	10:20 am	127	0.114		stir
Steam off	10:55 am	127			stir
Dipping	12:05 pm		0.025		draining of curd and whey
Pressing	overnight				
Brining	14-18 hrs.			5.2-5.3	saturated brine
Packaging					cryovac wrappers
Cooling	14-18 days	40			
Curing	6-8 weeks	70			

salting. The weight of the unsalted trim was also taken and converted to the salted weight on the basis of the weight change of the cheese during salting. The actual yields of Swiss cheese were calculated by adding the weight of cheese after salting plus the corrected weight of unsalted trim.

Cheese Analysis

Swiss cheese samples were analyzed for fat, protein and moisture. Fat was estimated by a modified Babcock procedure (52). Protein was estimated by the following modification of the Kjeldahl method (3):

Swiss cheese (0.8 - 2 g) (prepared by forcing the cheese through a stainless steel screen), was placed in a Kjeldahl digestion flask along with 0.7 g. HgO, 15 g. Na_2SO_4 and 25 ml. H_2SO_4. The flask was boiled gently on a digestion rack until the foam disappeared, then the heat was increased until the solution was entirely clear.

After the samples were cooled, 200 ml. distilled water were added. The samples were allowed to cool again, then 25 ml. sodium thiosulfate solution were added to precipitate Hg. Three or four pieces of mossy zinc were also added to prevent bumping during distillation. To a 500 ml. Erlenmeyer flask, 100 ml of saturated boric acid solution and two to four drops of methyl red-methylene blue indicator were added to each flask. The receiving Erlenmeyer flasks were placed at the end of the condenser adapter, making sure that the end of the glass tube was below the surface of the liquid. Seventy milliliters of 50% NaOH were allowed to drain carefully to the bottom of the digestion flasks without agitation, the flasks were quickly and firmly attached to the condenser. The solution was allowed to boil until about one-fourth of the liquid had distilled over.

The ammonia held in the boric acid was titrated with 0.1 N. HCl. The titration value of the blank was substracted from that of the sample. The percent total nitrogen was calculated and converted to protein by multiplying by a factor of 6.38. Percent casein was calculated by multiplying percent protein by .78 (10).

Cheese moisture was estimated by the procedure of Price et al. (36). A scheme of sampling and testing procedures is shown in Figure 1.

Statistical Analysis

A Tektronix laboratory computer 4051 (Tektronix, Beaverton, Oregon, U.S.A.) was used to analyze the data by applying the Gauss-Newton non-linear least squares method of iteration (40) (the data have been listed in Appendix).

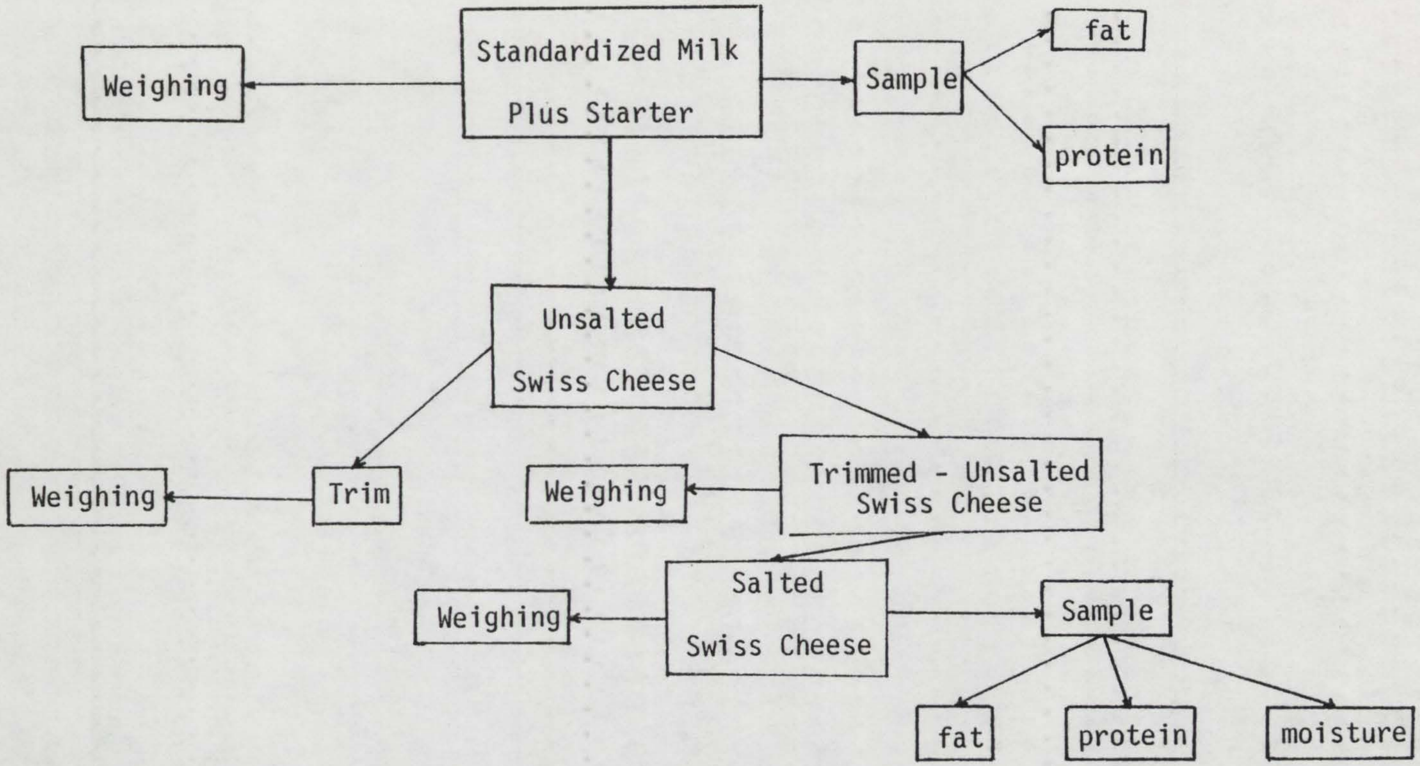
Starting values for the parameters in the equation being fitted were chosen. These values were modified by iteration until the residual sum of squares was minimized. The average fat recovery factor, casein lost factor or casein recovery factor and milk solids retained in cheese other than fat and casein as a percentage of cheese fat and casein (.78 P) were calculated for all samples and were used as starting values.

The following models were tested against the data:

Model I

$$Y = \frac{(aF + (0.78P - b))d}{1 - W}$$

Figure 1. Schematic of sampling and testing procedure.


Weighing
Standardized Milk
Plus Starter
Sample
fat
protein
Unsalted
Swiss Cheese
Weighing
Trim
Weighing
Trimmed - Unsalted
Swiss Cheese
Weighing
Salted
Swiss Cheese
Sample
fat
protein
moisture

where:

a = percent milk fat that goes to cheese

b = kilograms of milk casein that is lost in the whey per 100 kilograms of milk

d = one plus the amount of salts and solids other than fat and casein as a percentage of cheese fat and casein.

This is a modification of the original Van Slyke and Price formula (52) in which 0.78P has been substituted for C because of the difficulty of testing for casein. It was chosen because of its demonstrated accuracy and widespread use for predicting Cheddar cheese yields.

Model II

$$Y = \frac{(aF + bX.78P)d}{1-W}$$

where:

a = percent milk fat that goes to cheese

b = percent milk casein that goes to cheese

d = one plus the amount of salts and milk solids other than fat and casein as percentage of cheese fat and casein

Model II is similar to the modified Van Slyke and Price model except that it assumes that the milk protein lost to the whey is a function of the protein content in the milk. The Van Slyke and Price formula (52) assumes that a constant amount of casein is lost from each 100 kilograms of milk regardless of the amount in the milk.

Model III

$$Y = \frac{ab^{.78P/F}F + c.78P}{1 - W}$$

where:

$ab^{C/F}$ = percent milk fat that goes to cheese times one plus the amount of added salts and milk solids other than fat and casein as a percentage of fat and casein in cheese

C/F = casein to fat ratio of milk

c = percent milk casein that goes to cheese times one plus the added salts and milk solids other than fat and casein as a percent of cheese fat and casein

Model III recognizes that fat recovery in the cheese must be a function of the casein to fat ratio in the milk. Curd from milk with very high fat and very low casein should not hold as much fat as milk with more protein and less fat.

For all models:

Y = cheese yield (kilograms) per 100 kilograms of milk

F = percent fat in milk

.78P = .78 x percent protein in milk (percent casein in milk)

W = kilograms of water per kilogram of cheese.

The correlation coefficients between the actual yield and the predicted yields by the three equations were also calculated.

RESULTS

By applying Gauss-Newton non-linear least squares method of iteration to the data to fit the three models, the following results were obtained:

<u>Model I</u>

$$Y = \frac{(aF + (.78P-b))d}{1-W} = \frac{(0.77F + (0.78P-0.2))1.1004}{1-W}$$

where:

a = 0.77. Suggests that 77% of milk fat goes to cheese.

b = 0.2. Suggests that 0.2 kilograms of milk casein per 100 kilograms of milk are lost in the whey.

d = 1.1004. Indicates that added salts and milk solids other than fat and casein represent 10.04% of cheese fat and casein.

<u>Model II</u>

$$Y = \frac{(aF + b.78P)d}{1-W} = \frac{(0.72F + 0.99 \quad 0.78P)\, 1.095}{1-W}$$

where:

a = 0.72. Suggests that 72% of milk fat goes to cheese

b = 0.99. Suggests that 99% of milk casein goes to cheese

d = 1.095. Indicates that milk solids other than fat and casein plus added salts represent 9.5% of the cheese fat and casein.

This equation could be modified to become:

$$Y = \frac{0.788\ F + 0.845\ P}{1-W}$$

where:

$0.788 = 0.72 \times 1.095$

$0.845 = 0.99 \times 0.78 \times 1.095$

<u>Model III</u>

$$Y = \frac{ab^{.78P/F}F + c \cdot 0.78P}{1-W} = \frac{(0.44)(1.97)^{.78P/F}F + 1.076 \times 0.78P}{1-W}$$

where:

$ab^{.78P/F} = (0.44)(1.97)^{.78P/F}$ represents percent milk fat that goes to cheese times added salts and milk solids other than fat and casein as a percent of cheese fat and casein.

$c = 1.076$ represents percent milk casein that goes to cheese times added salts and milk solids other than fat and casein as a percent of cheese fat and casein.

Model III could be modified to become:

$Y = (0.44)(1.97)^{.78P/F}F + 0.84P/1-W$

where:

$0.84 = 1.076 \times 0.78$

For all models:

Y = kilograms of cheese per 100 kilograms of milk

F = percent fat in milk

.78P = 78 x percent protein in milk (percent casein in milk)

W = kilograms of water per kilogram of cheese

The correlation coefficients (r) between the actual yields and the predicted yields, and the residual sum of squares (RSS), are shown in Table 7. The regression lines resulting from plotting actual yields versus predicted yields by the models are shown in Figures 2, 3

Table 8. The correlation coefficients (r) and the residual sum of squares of the models.

	Model	r	RSS
I	Y = (0.77 + (.78P-0.2)) 1.1004/1-W	0.734	4.88
II	Y = 0.788F + 1.08.78XP/1-W	0.738	4.57
III	$Y = (0.44)(1.97)^{.78P/F}F +$ 1.076X.78P/1-W	0.736	4.29

and 4.

The improvement in the residual sum of squares of the models after iterations is shown in Table 8. The starting and the final values of the parameters are also listed.

Table 9. Starting and final values of parameters and residual sum of squares.

Models	Parameters	Starting Values	RSS (initial)	Final Values	RSS (final)
I	a	0.73		0.77	
	b	0.53	5.23	0.2	4.88
	d	1.22		1.1	
II	a	0.73		0.72	
	b	0.80	5.26	0.99	4.57
	d	1.22		1.095	
III	a	.5		0.44	
	b	2.18	8.45	1.97	4.29
	c	1.54		1.076	

Figure 2. The regression line obtained from plotting predicted yields by the equation $Y_1 = (0.77F + .78P-0.2)1.1004/1-W$ versus actual yields.

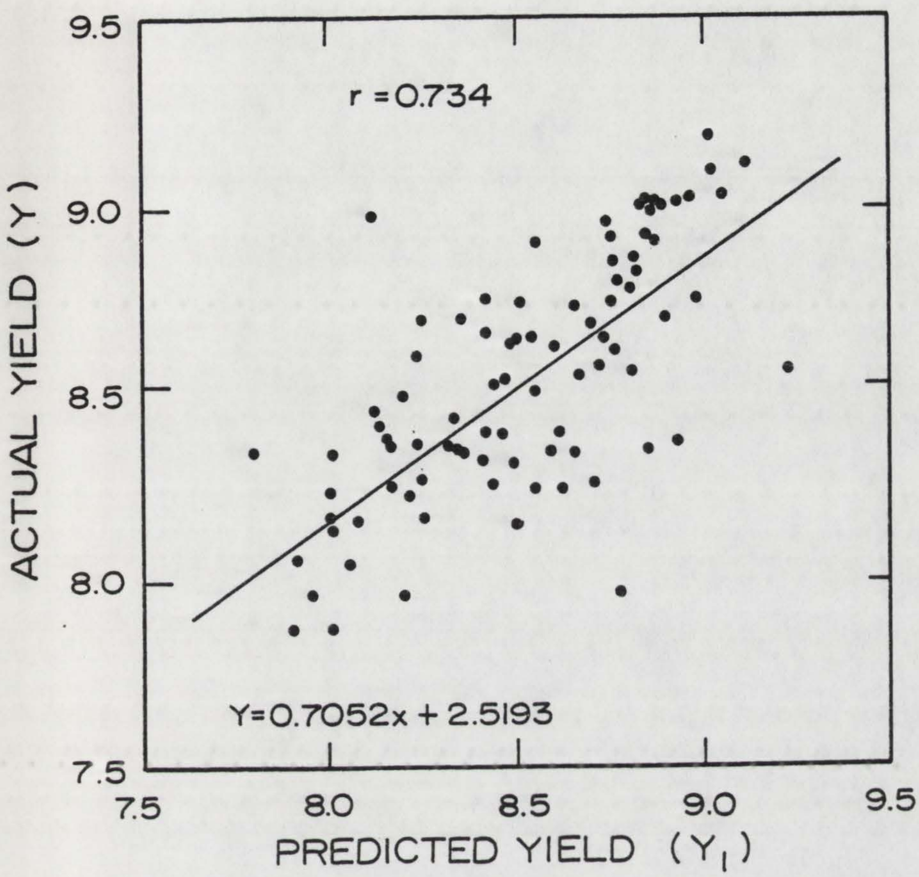

r = 0.734
Y=0.7052x + 2.5193
ACTUAL YIELD (Y)
PREDICTED YIELD (Y$_1$)
9.5
9.0
8.5
8.0
7.5
7.5
8.0
8.5
9.0
9.5

Figure 3. The regression line obtained by plotting predicted yields by equation $Y_2 = (0.788F + 0.845P)/1\text{-}W$ versus actual yields.

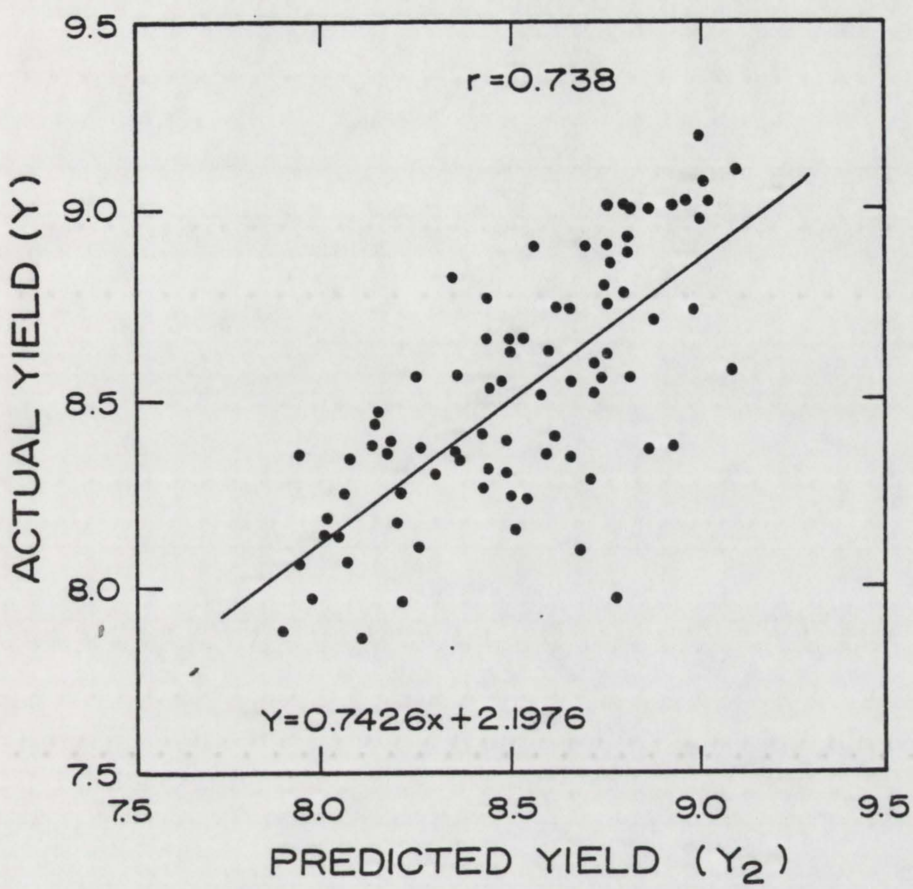
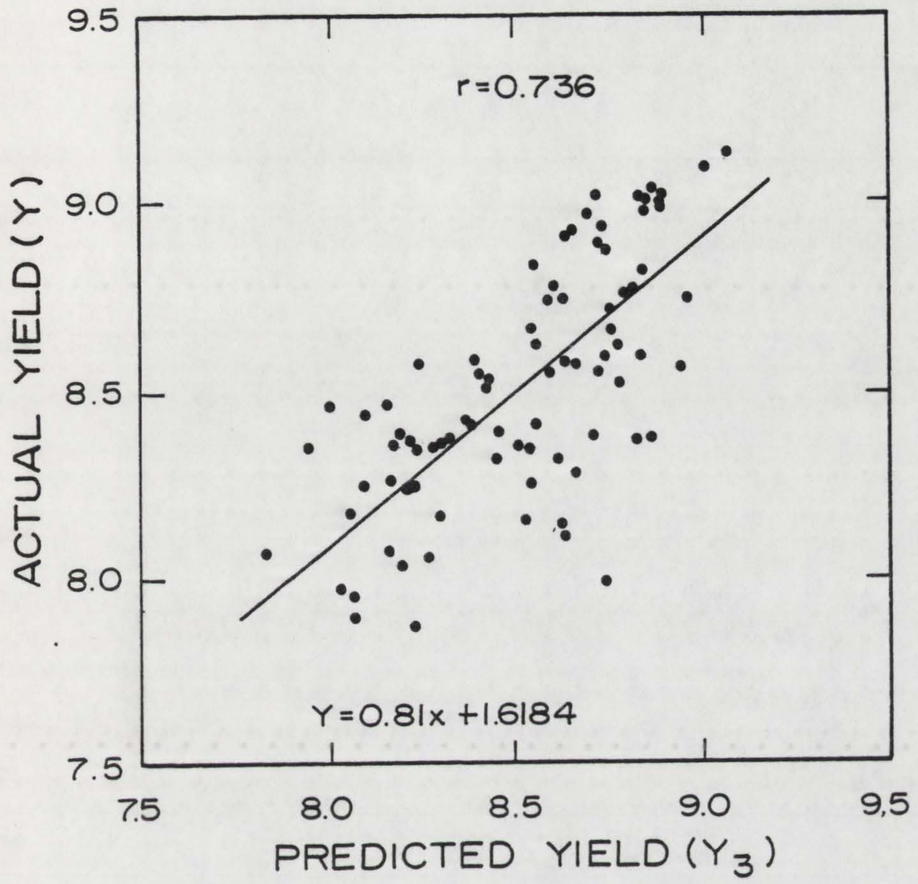

r =0.738
Y=0.7426x+2.1976
ACTUAL YIELD (Y)
PREDICTED YIELD (Y_2)
9.5
9.0
8.5
8.0
7.5
7.5
8.0
8.5
9.0
9.5

Figure 4. The regression line obtained by plotting predicted yields by the equation $Y_3 = (0.44)\ (1.97)^{.78P/F_F} + 0.84P/1\text{-}W$ versus actual yields.



r=0.736
Y=0.81x +1.6184
ACTUAL YIELD (Y)
PREDICTED YIELD (Y3)
9.5
9.0
8.5
8.0
7.5
7.5
8.0
8.5
9.0
9.5

Seasonal Changes in Swiss Cheese Yields

Average actual yields of Swiss cheese for each month were calculated. Average percent milk fat and protein for each month were also calculated (Appendix). Average actual yields of Swiss cheese (corrected to 39% moisture) for each month were plotted versus the month to indicate the fluctuation in yields during the year (Figure 5). Average percent milk fat and protein were plotted versus the months to show the variation in percent fat and protein in the standardized Swiss cheese milk (Figure 6).

The highest Swiss cheese yield (corrected to 39% moisture) was in December. The lowest yield was in June (Figure 5). The highest and the lowest protein content of Swiss cheese milk was during October and July respectively while the highest and the lowest fat cntent in the standardized Swiss cheese milk was in November and May respectively (Figure 6). Figure 7 shows a comparison between fat plus protein of the standardized Swiss cheese milk and cheese yields (corrected to 39% moisture) during the year. The highest fat plus protein was in October, November and December, and the highest yields were in November and December. The lowest fat plus protein was in May and August and the lowest yields were in May, June and July.

Figure 5. Yields of Swiss cheese throughout one year at Cache Valley Dairy Association (corrected to 39% moisture).

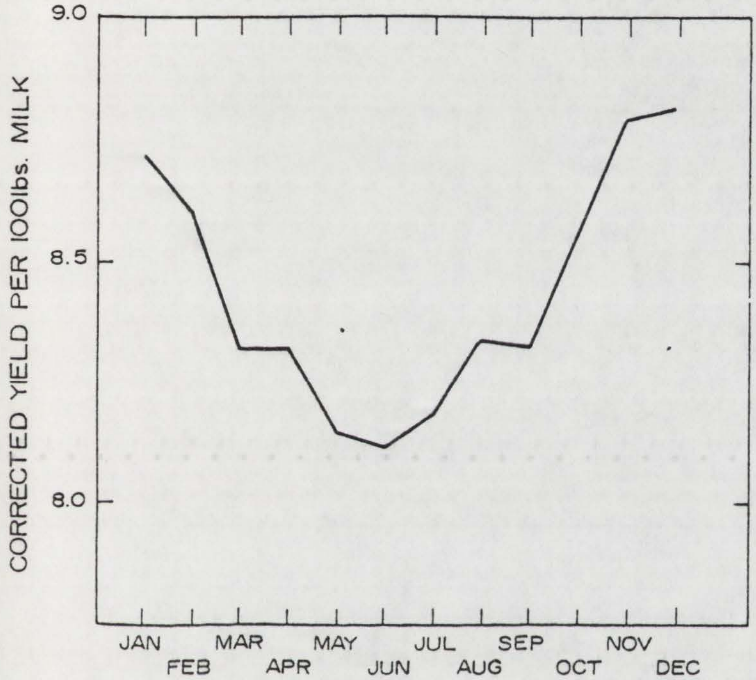

CORRECTED YIELD PER 100lbs. MILK
9.0
8.5
8.0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Figure 6. Percent fat and protein in standardized milk for Swiss cheese making throughout one year at Cache Valley Dairy Association.

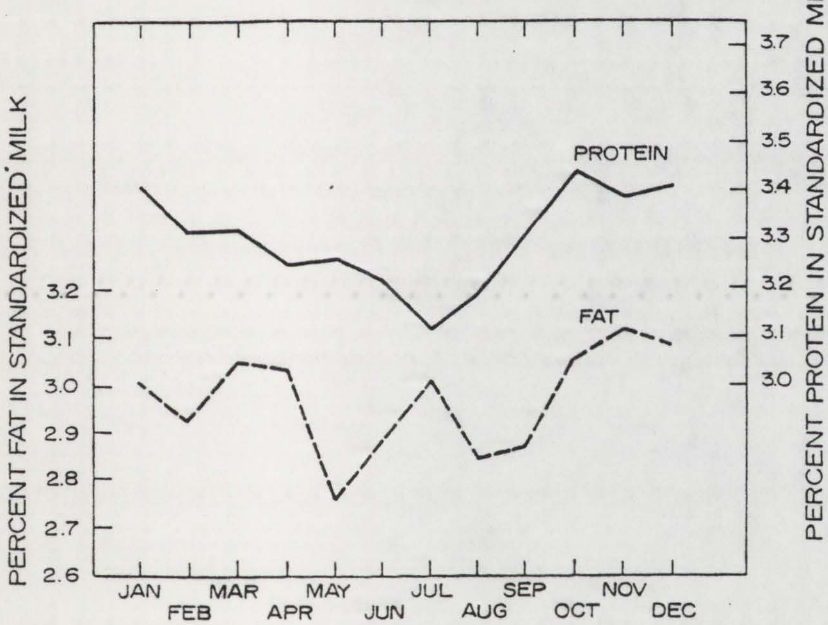
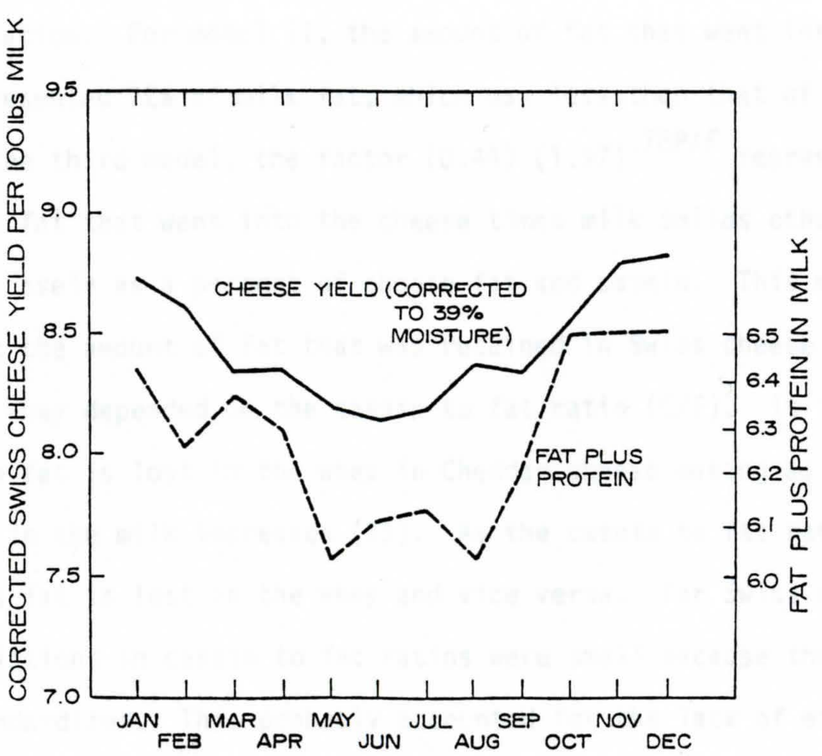

PERCENT FAT IN STANDARDIZED MILK
PERCENT PROTEIN IN STANDARDIZED MILK
PROTEIN
FAT
3.2
3.1
3.0
2.9
2.8
2.7
2.6
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Figure 7. Comparison of Swiss cheese yields (corrected to 39% moisture) with fat plus protein of the standardized milk throghout one year at Cache Valley Dairy Association.


CORRECTED SWISS CHEESE YIELD PER 100 lbs MILK
9.5
9.0
8.5
8.0
7.5
7.0
CHEESE YIELD (CORRECTED TO 39% MOISTURE)
FAT PLUS PROTEIN
FAT PLUS PROTEIN IN MILK
6.5
6.4
6.3
6.2
6.1
6.0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

DISCUSSION

In manufacturing Swiss cheese more fat is lost in the whey than in Cheddar cheese making (22). For model I, about 77% of the milk fat was recovered in Swiss cheese, which meant there was a loss of 23% of the milk fat in the whey, while in Cheddar cheese the loss is 7-10% (52). This higher fat loss is due to cutting when the curd is softer, smaller curd cuts, higher cooking temperature, and more vigorous agitation. For model II, the amount of fat that went into the cheese represented 72% of milk fat, which was less than that of equation I. In the third model, the factor $(0.44)\ (1.97)^{.78P/F}$ represented percent milk fat that went into the cheese times milk solids other than fat and casein as a percent of cheese fat and casein. This model assumed that the amount of fat that was retained in Swiss cheese or lost in the whey depended on the casein to fat ratio (C/F). It is known that more fat is lost in the whey in Cheddar cheese making as the percent fat in the milk increases (35). As the casein to fat ratio increases, less fat is lost in the whey and vice versa. For Swiss cheese milk, variations in casein to fat ratios were small because the milk was standardized. This probably accounted for the lack of effect of casein to fat ratios on yields of Swiss cheese. Milk for some other cheese varieties like Cheddar varies considerably in casein to fat ratio, therefore the third model may fit these varieties better than Swiss cheese.

The casein lost factor in equation I represents that 0.2 kilograms of milk casein per 100 kilograms of milk were lost in the whey, which is higher than for Cheddar cheese. In equation II one percent of the milk casein was lost in the whey. In equation III, the factor 1.076 represents the percent milk casein that went to the cheese multiplied by the added salts and milk solids other than fat and casein that were increased in the cheese.

Added salt and other milk solids (other than fat and casein) in equation I represent 10.04% of the cheese fat and casein, which is higher than that for Cheddar cheese, (in Cheddar cheese they represent 9 percent of the cheese fat and casein). In equation II, they represented 9.5% of the cheese fat and casein which was also higher than that of Cheddar cheese. In equation III they are included with the percent milk fat and casein that goes to the cheese.

The residual sum of squares for the three equations were 4.88, 4.57 and 4.29 respectively (Table 7). The smaller the residual sum of squares, the better the equation; but the differences between the three residual sums of squares were insignificant.

The regression lines of the three equations are shown in figures 2, 3 and 4. The correlation coefficient (r) between the actual yields and the predicted yields by the first equation was less than that by the second and third equations (Table 7). However the differences among the three correlation coefficients were very small and considered insignificant. Each of the three equations can be used to predict the yield of Swiss cheese reasonably well. On the other hand the second equation is simpler than the other two equations.

Actual yields of Swiss cheese at the Cache Valley Dairy Association (corrected to 39% moisture) were at a maximum in December. The yields decreased until they reached a minimum in June, then they increased again (Figure 6). This was mainly due to the effect of season on milk fat and protein content as shown by many authors (13, 18, 33, 34, 38, 41, 43, 54). The highest percentage of milk fat plus protein in standardized Swiss cheese milk was in October, November and December, and the lowest was in May (Figure 7). There was a relationship between milk fat plus protein and cheese yield, but it do not accurately predict the yield (18) (Figure 7).

Protein content of the standardized milk for Swiss cheese making, was the highest during October and the lowest during August (Figure 5). Irvin (18) and Steinsholt and Ystgaard (43) showed the same result for Cheddar cheese milk. Fat content of the standardized milk was highest during November and lowest during May (Figure 5). Irvin (18) also found that milk fat was highest in November but lowest in July throughout 1972.

The relationship between fat and protein content of Swiss cheese milk is shown in Figure 5. As protein content of the standardized milk increased, fat content decreased and vice versa, except during May, fat content decreased while protein content increased, and during July and November, fat content increased while protein content decreased. This indicates that the cheese milk was not standardized to a constant protein to fat ratio.

This work shows clearly that Swiss cheese yield can be predicted by any of the following equations:

1. $Y = [0.77F + (0.78P - 0.2)]\ 1.1004/1\text{-}W$
2. $Y = 0.788F + 0.84P/1\text{-}W$
3. $Y = (0.44)\ (1.97)^{.78P/F}F + 0.84P/1\text{-}W$

which differ from most previous equations because they predict Swiss cheese yield and they use protein measurement rather than casein.

These Swiss cheese yield equations could be improved to estimate yields more accurately as follows:

1. Fat recovered in the cheese in this study was determined entirely from cheese fat analysis and cheese weights. It was assumed that fat which is not accounted for in this manner was lost in the whey. Increased confidence in fat accountability would have been gained if the fat lost in the whey had been actually measured. The fat may not be uniformly distributed throughout the cheese since the salt and mositure were not at equilibrium at the time samples were taken.
2. For similar reasons it is suggested also that protein as well as fat analysis of whey be made in further studies.
3. Milk casein should be measured directly rather than estimating from total milk protein (by multiplying total milk proteins by a factor of 0.78). This is because the casein fraction of milk protein varies with the breed of cow (2, 10, 45, 52). Milk from Jersey cows would be better than milk from other breeds for cheese manufacturing because it has the highest casein as a percentage of total protein (10).

Further studies are needed, and should consider the above suggestions. Other studies also are recommended to test equations for predicting yield of other cheese varieties.

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APPENDIX

Table 10. Fat and protein contents of milk and the corresponding moisture content in Swiss cheese and cheese yield.

Month	Sample #	Actual yield/ 100 lb milk	Average	Milk Fat %	Average	Milk Protein %	Average	Cheese Moisture %	Average
	1	8.47	8.4	2.90	3.85	3.25	3.19	38.0982	39.02
	2	8.31		2.94		3.34		39.0013	
Aug.	3	8.35		2.684		3.112		39.4705	
	4	8.34		2.626		3.118		41.6161	
	5	8.38		3.00		3.17		38.9505	
	6	8.57		2.95		3.18		39.3636	
	7	8.37	8.43	2.98	2.88	3.20	3.32	39.4912	39.52
	8	8.40		3.08		3.30		39.4315	
Sept.	9	8.25		2.66		3.39		39.5267	
	10	8.38		2.67		3.44		39.9333	
	11	8.63		2.94		3.33		39.574	
	12	8.63		2.94		3.33		39.574	

Month	Sample #	Actual yield/ 100 lb milk	Average	Milk Fat %	Average	Milk Protein %	Average	Cheese Moisture %	Average
	13	8.74	8.59	3.10	3.06	3.40	3.441	38.2028	38.7022
	14	8.65		3.10		3.40		37.7834	
	15	8.10		2.65		3.43		39.6283	
	16	8.62		3.10		3.45		37.6691	
Oct.	17	8.59		3.06		3.46		38.6051	
	18	8.55		3.07		3.46		38.3725	
	19	8.75		3.09		3.44		39.0544	
	20	8.78		3.10		3.44		39.1873	
	21	8.38		3.21		3.46		38.8516	
	22	8.74		3.15		3.47		39.6678	
	23	8.90	8.885	2.98	3.12	3.35	3.38	39.5641	39.6128
	24	8.56		2.98		3.46		40.1096	
Nov.	25	8.77		2.85		3.36		39.7403	
	26	9.03		3.46		3.59		36.0761	
	27	8.98		3.26		3.26		41.3895	
	28	9.07		3.16		3.26		40.7971	

Month	Sample #	Actual yield/ 100 lb milk	Average	Milk Fat %	Average	Milk Protein %	Average	Cheese Moisture %	Average
	29	9.09	9.02	3.11	3.09	3.41	3.41	40.8310	40.3794
	30	9.11		3.14		3.41		41.1331	
Dec.	31	9.00		3.06		3.41		40.4382	
	32	8.80		3.01		3.43		39.8805	
	33	9.05		3.15		3.39		40.1036	
	34	9.05		3.08		3.41		39.8900	
	35	8.99	8.91	3.05	3.01	3.42	3.41	40.3089	40.2889
	36	9.01		3.04		3.41		40.2687	
Jan.	37	9.19		3.10		3.39		41.0881	
	38	9.02		3.08		3.40		40.825	
	39	8.59		2.97		3.43		39.9031	
	40	8.67		2.84		3.41		39.3397	
	41	8.91	8.76	3.14	2.95	3.29	3.32	39.9928	40.0242
	42	8.54		2.91		3.37		39.3661	
Feb.	43	3.92		3.15		3.34		39.8131	
	44	8.87		3.06		3.35		40.2283	
	45	8.83		2.71		3.30		41.0064	
	46	8.50		2.75		3.30		39.7383	

Month	Sample #	Actual yield/ 100 lb milk	Average	Milk Fat %	Average	Milk Protein %	Average	Cheese Moisture %	Average
	47	8.28	8.55	3.02	3.05	3.28	3.323	40.8307	40.5101
	48	8.73		3.08		3.33		39.4609	
	49	8.70		3.15		3.31		40.5839	
March	50	8.37		3.07		3.32		41.0875	
	51	8.65		3.02		3.38		40.027	
	52	8.61		3.00		3.32		41.0706	
	53	8.88	8.53	3.09	3.04	3.30	3.25	40.6923	40.2731
	54	8.96		3.06		3.31		40.3857	
	55	8.64		3.04		3.21		39.8915	
April	56	8.34		3.12		3.24		40.0162	
	57	8.35		3.07		3.25		39.9003	
	58	8.39		2.96		3.24		40.1133	
	59	8.15		2.93		3.22		40.9122	

Month	Sample #	Actual yield/ 100 lb milk	Average	Milk Fat %	Average	Milk Protein %	Average	Cheese Moisture %	Average
	60	8.37	8.29	2.87	2.767	3.19	3.26	39.4296	39.7552
	61	7.97		3.05		3.30		40.9289	
	62	8.40		3.00		3.25		39.3101	
May	63	8.43		2.90		3.25		39.6668	
	64	8.18		2.76		3.23		38.9118	
	65	8.14		2.75		3.25		38.8875	
	66	8.51		2.81		3.37		40.9968	
	67	8.31		3.00		3.24		39.9106	
	68	8.37	8.21	2.88	2.89	3.22	3.22	39.6485	39.5646
	69	8.17		2.79		3.21		40.0703	
	70	7.87		2.77		3.23		39.3313	
June	71	7.89		2.71		3.18		39.1909	
	72	8.57		3.59		3.18		39.8903	
	73	8.52		2.93		3.17		40.9772	
	74	8.24		2.77		3.26		38.6068	
	75	8.06		2.73		3.30		38.8018	

Month	Sample #	Actual yield/ 100 lb milk	Average	Milk Fat %	Average	Milk Protein %	Average	Cheese Moisture %	Average
	76	8.39	8.2	2.91	3.01	3.08	3.118	40.1164	39.1845
	77	8.43		2.86		3.09		40.2199	
	78	8.24		3.21		3.11		39.3505	
	79	8.24		3.28		3.11		38.9162	
July	80	8.35		3.07		3.24		38.3776	
	81	8.27		3.15		3.06		39.8403	
	82	7.96		3.02		3.14		38.6092	
	83	7.98		2.82		3.15		38.7921	
	84	8.07		2.91		3.09		38.0181	
	85	8.18		2.88		3.11		39.6051	